1-1-1988

The blocking of conditioned reinforcement.

David C. Palmer
University of Massachusetts Amherst

THE BLOCKING OF CONDITIONED REINFORCEMENT

A Dissertation Presented

by

DAVID CLIFTON PALMER

Submitted to the Graduate School of the
University of Massachusetts in partial fulfillment
of the requirements for the degree of

DOCTOR OF PHILOSOPHY

February 1988

Psychology

The Blocking of Conditioned Reinforcement

A Dissertation Presented

by

David Clifton Palmer

Approved as to style and content by:

John W. Donahoe, Chair

John J. B. Ayres, Member

Rachel K. Clifton, Member

Lawrence R. Klar, Jr., Member

Seymour M. Berger, Department Head
Psychology

ACKNOWLEDGEMENTS

I wish to thank Dr. John J. B. (Joe) Ayres, Dr. Lawrence R. Klar, Jr., and Dr. Rachel K. Clifton, members of my dissertation committee, all of whom provided cheerful support and helpful comments in the design of the study and in the preparation of the final document. It was Joe Ayres who convinced me of the need for two control groups in the experiment and hence deserves credit for whatever validity the study may have.

A study of this sort must be run every day of the week until it is done, with only a few opportunities for a break between conditions. I relied mainly on my wife, Jill Palmer, to run the study on those occasions when I was unavoidably called away. This was an invaluable service to me.

To acknowledge my debt to John Donahoe is no easy task. I might cite his technical skills, his programming skills, his editorial skills, his shrewdness in experimental design, his extraordinary grasp of the literature - seemingly in every field - and, not least, his deftness in heading a research laboratory with minimal interference from an irksome bureaucracy. These skills have made him the paragon of University advisors, but to me he has been far more. He has served as a model of intellectual integrity and a valued companion on a seldom travelled path.

ABSTRACT

THE BLOCKING OF CONDITIONED REINFORCEMENT

FEBRUARY 1988

DAVID CLIFTON PALMER, B.A., UNIVERSITY OF MASSACHUSETTS

M.S., UNIVERSITY OF MASSACHUSETTS

Ph.D., UNIVERSITY OF MASSACHUSETTS

Directed by: Professor John W. Donahoe

This experiment investigated whether a blocking paradigm in a Pavlovian procedure will produce blocking of the conditioned reinforcement function of a stimulus. Twenty-four pigeons were trained to peck two keys at approximately equal rates, following which, key pecking was extinguished. A blocking procedure was then conducted in two phases. In Phase I eight experimental birds received 360 pairings of a stimulus (a tone or a light) with food. In Phase II they received 360 pairings of a light-tone compound with food. Eight control birds received the same Phase I training as the experimental birds but in Phase II were given independent light-food and tone-food pairings. A second control group of eight birds received no Phase I training, but they received the the same Phase II training as the experimental birds. In a test phase, for all birds, pecks to one key were followed by presentations of the light, while pecks to the other were followed by presentations of the tone. The relative rate of key pecking was used as a

measure of the relative effectiveness of the two stimuli to serve as conditioned reinforcers. For the eight experimetal birds the Phase I stimulus was a more effective conditioned reinforcer than the other. For each of the control groups, both stimuli were approximately equally effective, suggesting that the conditioned reinforcement function of a stimulus can be blocked.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

C H A P T E R 1

INTRODUCTION

"Neutral" stimuli, stimuli that have no special biological importance to an organism, can, through conditioning procedures, acquire discriminative, eliciting, motivating, and reinforcing functions. If, in the presence of a red light, a hungry pigeon pecks a small disk, or "key," and is promptly presented with food, the red light may acquire all four functions. To the extent that presenting the red light reliably occasions key pecks, we speak of its discriminative function. If the red light controls gastric secretions, nibbling, or other behavior typically elicited by food, then we say that it serves an eliciting function. The red light may also alter the strength of a variety of loosely related elicitation processes. The pigeon may become more active and pace the chamber, search the floor, attack a rival, or engage in other available consummatory behavior. If so we speak of its motivating function. Finally, if we can increase the rate of a response, such as stepping on a treadle, by presenting the red light contingent on treadle responses, we say that the red light serves a reinforcing function.

(These distinctions are merely operational and may or may not reflect distinct processes in the organism.)

An organism for which arbitrary stimuli easily acquire these functions faces a potential problem: Countless arbitrary stimuli are paired with unconditioned reinforcers; if they all acquired conditioned functions the organism would be poorly served, for much useless behavior would be shaped, maintained and elicited. It appears to be adaptive, then, for only certain stimuli to become conditioned. Which stimuli acquire control depends on factors such as genetic variables, stimulus intensity, and the prior experience of the organism. It is the latter factor that is of special concern in the present study.

When a particular stimulus acquires control of a response it will tend to block control by coextensive stimuli in future contingencies (e.g. Kamin, 1968; 1969; Miles, 1970; vom Saal & Jenkins, 1970; Williams, 1975). For example, if a tone acquires control of a nictitating membrane response in a rabbit as a result of a classical conditioning procedure (Phase I), and a light-tone compound stimulus is subsequently paired with the same unconditioned stimulus (Phase II), the light will acquire little control of the response (Marchant & Moore, 1973). Similarly, in the operant procedure, if a red light is established as a discriminative stimulus for key-pecking in pigeons, a tone will acquire only diminished control of the response if it

is presented coextensively with the light in later trials (vom Saal and Jenkins, 1970; see also, Williams, 1975).

The extent to which control by the second stimulus will be blocked can vary widely. Kamin (1968, 1969), the first to study blocking systematically, found nearly complete blocking in a series of experiments using the conditioned suppression procedure with rats. However, later researchers have shown that the extent of the blocking effect depends on the spacing of trials, and on the consistency in the procedure from Phase I to Phase II, and on parameters such as stimulus intensity. Mackintosh (1975a) found that when Phase I trials were spaced 24 hours apart blocking was enhanced relative to a condition in which the trials were delivered in a single session. Moreover he found that after only one trial of Phase II training there was little evidence of any blocking at all, a finding confirmed by Mackintosh, Dickinson, & Cotton (1980). The blocking effect has also been shown to be sensitive to consistency in the reinforcer parameters from Phase I to Phase II. If the reinforcer either increases or decreases in magnitude or duration, reduced blocking (or "unblocking") will occur (Dickinson, Hall, & Mackintosh, 1978; Holland, 1984; Mackintosh, et al., 1980; Neely & Wagner, 1974). Qualitative stimulus properties may be relevant as well. Mackintosh (1975a) reports that in pilot work with rats he was able to reliably demonstrate blocking of a tone by a light but not of the light by the tone.

While the extent of blocking may vary from one procedure to the next, the phenomenon has been amply confirmed and has had a central influence on modern reinforcement theory. Reinforcement contingencies not only select behavior appropriate to a particular environment, they select which aspects of a complex environment will acquire or maintain control of the response in the future. The blocking of stimulus control is clearly adaptive for an organism since behavior will tend to come under the control of the most reliable predictor of reinforcement. "Superstitious" stimulus control (e.g. Morse and Skinner, 1957), control by stimuli adventitiously correlated with reinforcement, will be reduced. The reinforcement principle operates on coincidental events regardless of whether there is a causal relationship between them, but few events will coincide reliably unless there is, in fact, a causal relationship between them or they arise from a common cause.

Discrepancy Theories

Since Kamin's first demonstration of blocking, most conditioning theorists have regarded some form of "discrepancy" as central to any change in stimulus functions. Kamin himself suggested that learning requires "surprise," that is, a discrepancy between what an organism "expects" and what it gets. In what is perhaps the most influential formulation of the reinforcement principle, the

Rescorla-Wagner model, learning requires a discrepancy between realized and potential "associability" of the unconditioned stimulus (UCS) (Rescorla & Wagner, 1972). Others have suggested that the critical discrepancy pertains to the "associative strength" of the conditioned stimulus (CS) (e.g. Mackintosh, 1975b; Moore & Stickney, 1980; Pearce & Hall, 1980). Other researchers (e.g. Ayres, Albert, & Bombace (1987), Frey & Sears (1978); Wagner (1978)), have suggested that discrepancies pertaining to the associative strength of both stimuli affect learning. Another formulation of the reinforcement principle, the unified reinforcement principle of Donahoe, Crowley, Millard & Stickney (1982), dispenses entirely with the theoretical concepts of associability and associative strength, and dispenses likewise with the need to postulate a function that maps associations onto behavior. This formulation is congenial for the present purposes, as the critical discrepancy is couched entirely in terms of observable, or potentially observable, entities; it encompasses both the classical and instrumental procedures (hence the "unified" reinforcement principle); and it makes a specific prediction about the present study.

According to Donahoe, et al., changes in stimulus control in both the operant and classical procedures can occur only if there is a discrepancy between responses controlled by the unconditioned stimulus, or reinforcer, and

responses controlled by the constellation of stimuli that closely precede the reinforcer. Thus if we present a tone to a naive rabbit shortly before puffing air into the rabbit's eye there is a discrepancy between behavior to the tone (orienting responses) and behavior to the puff (nictitating membrane response). A change in stimulus control will occur, that is, the probability of a nictitating membrane response in the presence of the tone will increase. If, after we thoroughly condition the tone, we present the tone and a light as a compound CS followed by the same UCS, the probability of a membrane response to the compound CS is approximately equal to the probablility of a response to the puff of air, and no further changes in stimulus control occur. That is, the light does not acquire control of the nictitating membrane response (Marchant & Moore, 1973).

This theory predicts, then, that once a stimulus acquires control of a response it will serve as a conditioned reinforcer to alter the stimulus control of other (neutral) stimuli, since there will now be a discrepancy between responses to the neutral stimulus and responses to the conditioned reinforcer. According to this theory, the reinforcing function of a stimulus depends on (or is correlated with) its eliciting function, and it follows that if the eliciting function can be blocked the reinforcing function should be blocked as well.

As indicated above, blocking of the eliciting and discriminative functions has been demonstrated. Blocking of the conditioned reinforcing function of a stimulus has not yet been demonstrated, either in humans or in other organisms; yet, as noted, there are theoretical reasons why we should expect blocking to occur. Additionally, the adaptive significance of blocking with regard to the discriminative and eliciting functions of stimuli applies equally to the reinforcing function. Conditioned reinforcers are important in shaping and maintaining appropriate behavior when unconditioned reinforcers are delayed. An organism would be well served if it were reinforced only by those stimuli most reliably correlated with unconditioned reinforcement.

Experimental Evidence

While no one has yet demonstrated blocking in a conditioned reinforcement paradigm with the instrumental procedure, Bombace (1980) and Zimmer-Hart (reported in Rescorla, 1977) found blocking of higher-order conditioning in a classical conditioning paradigm. In higher-order conditioning a conditioned stimulus is used as the eliciting stimulus in a Pavlovian procedure to condition a second, neutral stimulus. Since higher-order conditioning is procedurally and conceptually analogous to conditioned reinforcement in the instrumental procedure, and since the distinction between Pavlovian and instrumental conditioning

is clear only at the procedural level, these findings suggest that the conditioned reinforcement function can be blocked as well.

Blanchard & Honig (1976) showed that the effectiveness of a reinforcer is diminished if that reinforcer is predicted by the context in which it is presented. Food was delivered to hungry pigeons in one context (colored houselight) irrespective of the behavior of the birds. In a second context food was withheld. Subsequently, in an autoshaping procedure with a white key light, acquisition of key pecking was superior in the second context. This result was replicated with auditory stimuli as the blocking stimulus (Leyland & Mackintosh, 1978; Tomie, 1976a) and with apparatus cues as the blocking stimulus (Tomie, 1976b). If the effectiveness of a reinforcer in an autoshaping procedure is a measure of the effectiveness of a reinforcer in a conditioned reinforcement paradigm, then these studies predict that the conditioned reinforcement function of a redundant stimulus will be blocked.

Further suggestive evidence has been provided by Egger & Miller (1962) in an instrumental procedure using compound conditioned reinforcers with rats. They paired two stimuli of unequal length with food; the onset of the longer stimulus preceded the onset of the shorter by one-half second. They found that the shorter stimulus was a weaker conditioned reinforcer than the longer, except under

conditions in which the longer stimulus was manipulated in such a way as to render it an unreliable predictor of reinforcement. They concluded that a redundant, uninformative stimulus would acquire less strength as a conditioned reinforcer than an informative one. This result has been confirmed by McCausland, Menzer, Dempsey, & Birkimer (1967), Seligman (1966), and Thomas, Berman, Serednesky, & Lyons (1968), but Hancock (1982) showed that when one controlled for differential generalization from training to testing the opposite result obtained. However, Hancock concluded that a modification of Egger & Miller's information hypothesis was still tenable.

Suggestive though they are, none of these experiments provides direct evidence that the conditioned reinforcement function can be blocked. The present study was designed to put the matter to experimental test.

Procedural Issues

Conditioned reinforcement has proven refractory to straightforward investigation. Rescorla (1977), commenting that "The phenomenon of secondary instrumental reinforcement has been notorious both in its technical difficulties and its elusiveness of demonstration," suggests that the principal difficulty is that an extinction procedure is inherent in any valid test of the phenomenon. That is, every occasion on which the putative conditioned reinforcer

is presented alone is an extinction trial. This limitation is unavoidable; pairings of the conditioned reinforcer with the UCS during a test phase raise the possibility that any responding is maintained in part by presentations of the UCS. If "refresher" stimulus pairings are scheduled after a specified period without a response, then there is a danger of reduced responding, since response-produced stimuli are never followed by reinforcement. If a free-operant training procedure is used in which responses produce the conditioned reinforcer followed by the unconditioned reinforcer, the conditioned reinforcer may acquire discriminative control over key pecking, since the stimulus following one response necessarily precedes the next. Finally, the test of a conditioned reinforcer is its effect on the strength of an instrumental response. As the acquisition of a novel response is usually quite variable from one animal to the next, the effect of a weak reinforcer can be obscured.

These considerations have suggested the following procedure, a modification of that employed by Egger and Miller (1962). Pigeons were trained to peck two keys on concurrent variable interval (VI) schedules under conditions that favored equal rates of responding on each key. (In an interval schedule of reinforcement, a specified time interval since the last reinforcer must elapse before a response will be reinforced again. In a variable interval schedule, this interval is not the same from one reinforcement to the next,

but varies around some average value. In a concurrent schedule, two or more different responses are reinforced on separate schedules.) Responding was then extinguished, and pairings of a neutral stimulus with food were introduced in a forward delay classical conditioning paradigm (i.e. the neutral stimulus precedes but overlaps the UCS temporally). Only one out of three presentations of the neutral stimuli were paired with food. Next, a second neutral stimulus was presented coextensively with the first and the classical procedure was repeated (a simultaneous compound paradigm). Finally, in the test phase the two putative conditioned reinforcers were presented contingent on key-pecking. One stimulus was presented contingent on pecks to the left key, the other on pecks to the right key.

This procedure avoids some of the problems and ambiguities that have plagued many conditioned reinforcement studies. First, the instrumental response, the conditioned reinforcer and the unconditioned reinforcer do not occur together. Therefore the conditioned reinforcer cannot serve a discriminative function. Second, reacquisition of an extinguished response is faster and less variable than the acquisition of a novel response, at least when the original reinforcer is used. Presumably the response will be relatively sensitive to any reinforcing effect of the putative conditioned reinforcers. Therefore it may be possible to obtain a measure of the relative strengths of these reinforcing effects before extinction reduces or

obscures them and without the variability in responding typical of novel responses. Finally, the procedure permits both within-subject and between-subject measures of blocking. If the two stimuli are equally strong reinforcers the subjects should show little systematic preference for one key over the other. In the absence of blocking we would expect this condition to hold, provided that training is prolonged enough to ensure asymptotic conditioning to both stimuli. A between-groups comparison of preference is of course still necessary to control for the differences in exposure to the two stimuli and for unconditioned differences in the effects of the stimuli. (These considerations will be discussed more explicitly below when the details of the procedure are presented.)

Equating Conditioned Stimuli

A difficulty that must be overcome in a demonstration of blocking is that neutral stimuli may not acquire conditioned functions equally effectively. The validity of the study depends on finding appropriate parameters for the neutral stimuli so that one does not overshadow the other. (We speak of overshadowing when, owing to unknown or extra-experimental factors, one stimulus acquires or exerts more control than a coextensive stimulus.) For example, Foree and LoLordo (1973) and Randich, Klein, and LoLordo (1978) found that pigeons were more likely to come under the

control of a visual discriminative stimulus than an auditory discriminative stimulus when food was used as a reinforcer. In the latter study a response to one treadle was reinforced in the presence of an 80 dB tone while a response to the second treadle was reinforced in the presence of an 8.57 candela/m^2 (cd/m^2) white light. When the stimuli were presented simultaneously the pigeons responded exclusively on the second treadle (the "light" treadle). In the laboratory of the author and his colleagues, comparable results have been obtained with similar parameters. However, we have found that under some combination of stimulus parameters the behavior of pigeons can be controlled roughly equally by both modalities. Stickney & Donahoe (1979), using a key pecking response in an operant procedure, found that a 90 dB interrupted tone and a 3 cd/m^2 diffuse white light exerted comparable control over behavior.

To confirm Stickney's result and to extend it to the stimuli to be used in the present experiment, I carried out the following parameter study:

Five pigeons were individually shaped to peck a single white key. When the response was well established a discrimination procedure was begun. In the presence of a compound stimulus, which was presented on a variable time 120 sec (VT 120) schedule, reinforcement of keypecking was delivered on a VI 15 schedule. Reinforcement terminated the

stimulus, and in the absence of the stimulus reinforcement was unavailable. For each bird one of the elements of the compound was a 90 dB tone interrupted briefly every 0.5 sec. The other element of the compound was a diffuse red light (22 cm by 17 cm) centered in the ceiling of the chamber. The intensity of the light was constant for each pigeon but varied from pigeon to pigeon as indicated in Table 1. Intensities of 1, 2, 3, 4, and 15 cd/m^2 were used. After 13 sessions of discrimination training the elements of the compound were tested alone for discriminative control. The results are summarized in Table 1. The light completely overshadowed the tone at 4 and 15 cd/m^2, while the tone completely overshadowed the light at 1 cd/m^2. At 2 cd/m^2 the tone was dominant and at 3 cd/m^2 the light was dominant, but in neither case was the dominance exclusive.

Table 1

Experimental conditions and results in the parameter study.

Bird #	Tone (dB)	Light (cd/m^2)	Pecks to Light	Pecks to Tone	Preference * for Light
25	90	1	1	184	.005
26	90	2	88	208	.309
27	90	3	122	26	.831
28	90	4	164	5	.972
29	90	15	144	13	.921

The orderly relationship between the intensity of the light and the relative control by the light, together with Stickney's results, suggested that a stimulus intensity between 1 and 2 cd/m^2 be used. A single indifference point for all birds is probably unattainable, but, in any case, a bias leading to spurious evidence for blocking for one group will be a bias against blocking for the counterbalanced group. Moreover, the control group should reveal the extent of any bias.

In a study in which preference between two responses is being measured, it is essential that there be no competing behavior that might interact differentially with the target responses. Since conditioned reinforcers typically serve a discriminative function (e.g. Dinsmoor, (1950); Keller & Schoenfeld, 1950; Thomas & Caronite, 1964) and presumably serve an eliciting function as well, one must take care that the behavior controlled by the stimuli is neutral. Pilot work revealed the importance of the location of the stimuli. Visual stimuli scheduled to become conditioned reinforcers elicited orienting behavior that, because of their location, differentially favored pecks to the right key. (The visual stimuli were presented through the one-way mirror in the door of the chamber. Pigeons tended to face the one-way mirror, particularly when the light was on.) Consequently, the visual stimulus was moved to a central position in the ceiling of the chamber, and the speaker presenting the tone

was positioned so that the maximum intensity was at the food hopper, between and below the response keys.

Consideration of behavior controlled by the contingently presented stimuli suggests that these stimuli should be presented briefly. Immediately after a pigeon has pecked a key it is in an optimal position to peck it again, and the precise conditions under which it pecks are those under which it is reinforced. To the extent to which the reinforcer takes the pigeon away from the key, performance as measured by pecking will be impaired. This is unavoidable when food is used as a reinforcer, but tones and lights need not disrupt responding. If the stimuli are prolonged, however, keypecking is apt to be disrupted, for even an orienting response will presumably diminish control by the key and related stimuli. Perhaps the best controlled experiment and, hence, the most convincing demonstration of conditioned reinforcement was carried out by Hyde (1975), using a three second stimulus. This duration seemed short enough to reduce the problem of competing elicited behavior and had the added advantage of being the same duration as the unconditioned reinforcer; hence it was used here.

C H A P T E R 2

PROCEDURE

Subjects

Twenty-four naive White Carneau pigeons were maintained at approximately 80% of their free-feeding weights by supplementing the food obtained during the experimental session with a measured ration given 30 to 60 minutes after the end of each session. Twelve of the birds were approximately six months old at the start of the experiment; the other birds were adults more than two years old. The pigeons were caged singly in a colony room, and had free access to water.

Apparatus

Three two-key experimental chambers (Lehigh Valley Electronics) were interfaced with a laboratory microcomputer (Leading Edge) which controlled the presentation of events and monitored keypecks. Extraneous noise was masked by 75 dB white noise, and ventilation was provided by an exhaust fan in each chamber. A food magazine located at the base of the center of the intelligence panel delivered Purina pigeon chow in pellet form. General illumination was provided by a

houselight at the top of the intelligence panel, while auditory stimuli were presented by a speaker located five cm to the left of the food magazine and in back of the panel. A tone, interrupted briefly every 0.5 sec, was used as the auditory CS. The intensity of the tone was 90 dB at the opening of the food hopper, but varied somewhat within the chamber. The intensity was about 85 dB a few cms in front of the keys where a pigeon's head would tend to be located.

Those visual stimuli that were deliberately manipulated were of two sorts: white light transilluminating the keys and red light presented diffusely through a 22 cm by 17 cm opening centered in the top of the chamber. A light box, 18 cm by 30 cm by 7 cm, containing a single 15 watt, 120 volt light bulb, was fastened to the top of each chamber over this opening. The intensity of the light was controlled by a rheostat. The side of the box facing down into the chamber was white frosted Plexiglas, while the remaining interior walls of the light box were lined with aluminum foil. The light bulb was located at one end of the box, so that it did not shine directly into the chamber. The color of the light was imparted by red acetate film separating the bulb from the rest of the box. (See Figure 1.) The light entering the chamber was reflected off the foil walls and passed through the frosted Plexiglas. This arrangement was designed to present a diffuse light without "hot spots." Thus both the red light and the tone were diffuse stimuli

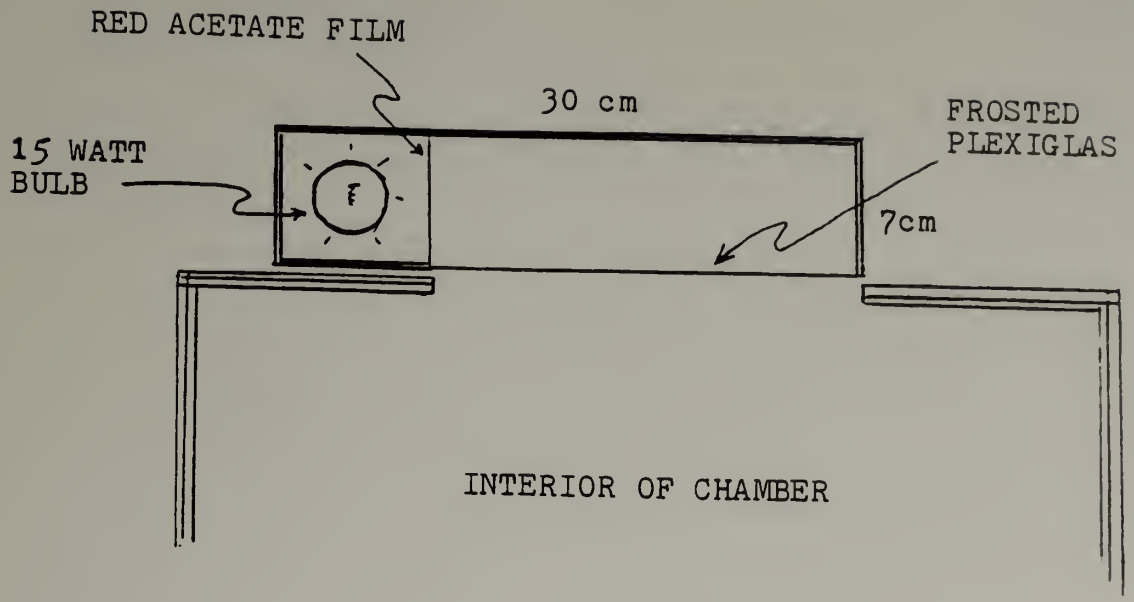


Fig. 1. Schematic diagram of light box.

designed to elicit little, if any, directed pecking. Since a localized stimulus paired with food will typically elicit pecking in pigeons (Brown & Jenkins, 1969), these "autoshaped" pecks can be confounding variables in experiments that measure rates of keypecking under the control of other stimuli (Palmer, Donahoe, & Crowley, 1985).

Response keys could be transilluminated with white light from an Industrial Electronic Engineering projector located behind each key.

Procedure

The birds were assigned to one of three groups of eight birds each: two control groups, and an experimental group. (See Table 2.) The six-month old birds were equally distributed among the three groups, but the assignment of birds to groups was otherwise random. Four of the birds in the experimental group were pretrained with the tone, and four were pretrained with the light. The pretrained stimulus or blocking stimulus is referred to as CS1 here, regardless of its modality. The to-be-blocked stimulus will be referred to as CS2. (As a mnemonic, we note that CS1 was present in the first phase of training, while CS2 was present only in the second phase.)

One control group (LT) received no pretraining, while the other control group (L/T) received the same pretraining as the experimental birds, i.e. half received pretraining with the tone, half with the light. Following pretraining this control group (L/T) received independent pairings of light and food and of tone and food. This group controlled for the fact that the experimental birds received twice as many pairings of CS1 with the reinforcer as of CS2 and the reinforcer. If the greater number of pairings results in a preference for one stimulus over the other then this preference should be apparent in the control birds as well. (The mnemonic "L/T" reminds us that this control group never

Table 2

Experimental design.

Bird #	Age	Phase I	Phase II
18	Y	T+	TL+
16	O	T+	TL+
6	O	T+	TL+
5	Y	T+	TL+
9	O	L+	TL+
17	O	L+	TL+
1	Y	L+	TL+
3	Y	L+	TL+
4	Y	T+	T+/L+
10	O	T+	T+/L+
12	O	T+	T+/L+
11	Y	T+	T+/L+
2	O	L+	T+/L+
13	Y	L+	T+/L+
14	Y	L+	T+/L+
15	O	L+	T+/L+
7	Y	---	TL+
8	Y	---	TL+
20	O	---	TL+
19	Y	---	TL+
21	O	---	TL+
22	O	---	TL+
23	O	---	TL+
24	O	---	TL+

received compound light-tone pairings with food. LT birds did receive compound training.)

Prior to the first experimental session all 24 birds were feeder trained and then trained to peck the keys by the reinforcement of successive approximations of keypecks.

Baseline. All 24 birds received the same baseline training. Both keys were transilluminated with white light and pecks to the keys were reinforced on concurrent variable-interval 15 sec schedules. When a peck met the schedule requirement the food hopper was raised for 3 sec, the hopper light came on, and all other lights were turned off. When the temporal criterion had been met for the reinforcement schedule for one key, the schedule for the other key stopped timing as well, so that every scheduled reinforcer was collected on its appropriate key before the schedules advanced. The purpose of this procedure was to encourage roughly equal rates of pecking on both keys (Herrnstein, 1961; Skinner, 1950). Each of the sessions was terminated after 30 food deliveries.

On subsequent sessions the concurrent schedules were attenuated to VI 30, VI 60, VI 90, and VI 120. The birds were run for a minimum of 28 days, or until rates of responding on the two keys stabilized. On the last two baseline sessions extinction was scheduled for all birds. Additional extinction sessions were provided, if necessary,

until responding declined to a rate of fewer than 30 pecks per 15 minute period.

The VI training and subsequent extinction ensured that the birds would respond to each key at a low rate when the keylights were on. No keypecks were reinforced with food for the remainder of the experiment, and the keys remained dark until the final condition of the experiment (the test phase). During the test phase the keylights were turned on and pecks were followed by presentation of the putative conditioned reinforcers, the to-be-blocked stimulus on one key and the blocking stimulus on the other key. Thus the purpose of the baseline phase was to establish two responses at low strength. Since the responses were strong prior to extinction, the test phase was a reconditioning procedure with different reinforcers.

Pretraining. In this phase the experimental birds received pairings of CS1 with the UCS, where CS1 was the nominal conditioned reinforcer appropriate for that group. Half of the control birds (LT) remained in their home cages during this phase. The other control group (L/T) received pairings under the same conditions as the experimental birds. Half were pretrained with the tone, half with the light. All birds received 30 reinforcers per session on a VT 120-sec schedule for 12 sessions. This procedure gave each experimental bird 360 CS1-UCS pairings, well over the 100 or so pairings at which the acquisition of conditioned

reinforcement has been shown to be asymptotic (Bersch, 1951; Hall, 1951; Kelleher & Gollub, 1962; Miles, 1956). The 120-sec intertrial interval (ITI) was comparable to that at which autoshaping procedures are particularly effective. In an experiment to test the optimal parameters for autoshaping, Perkins, Beavers, Hancock, Hemmindinger, Hemmindinger, & Ricci (1975) found 120 sec ITIs to be considerably more effective than 60 sec ITIs and no less effective than 720 sec ITIs. There are no comparable parametric studies of conditioned reinforcement.

For each CS1-UCS pairing the interstimulus interval (ISI) was 2.5 sec, the CS1 duration 3 sec, and the feeder duration 3 sec. The optimal ISI in conditioned reinforcement studies appears to be 0.5-1 sec (Bersh, 1951; Jenkins, 1950; Kelleher & Gollub, 1962). A somewhat longer ISI was used in the present study for several reasons. The auditory stimulus was a tone interrupted every half second. To the extent that an interrupted tone is qualitatively different from a continuous tone, a one-cycle duration is an intrinsic property of the stimulus. Secondly, the duration of the conditioned stimuli and that of the reinforcer was the same so that the presentation of the conditioned reinforcers in the test phase would be as similar as possible to the presentation of food in the baseline phase. The half-second overlap of the CS with the UCS ensured that the relevant event predicting the UCS was CS onset and not CS offset. The CS did not overlap the UCS completely as it

was reasoned that after the first half-second of food delivery the pigeon's head would tend to be in the hopper, cutting off the view of the diffuse red light but not cutting off the interrupted tone. In fact, as the hopper was next to the speaker that presented the tone, the intensity of the tone would be greater for a pigeon with its head in the hopper than for a pigeon standing erect in the chamber. It was assumed that a half-second overlap would not appreciably alter the exposure of the birds to the two stimuli since orientation and approach to the hopper would take time.

Blocking Procedure. In this condition CS1 and CS2 were paired in a simultaneous compound paradigm with the unconditioned reinforcer. The paired stimuli were presented on the same schedule and for the same number of sessions as in the pretraining phase for both the experimental and control group LT birds. Control group L/T birds received twice the number of stimulus-reinforcer pairings, but half were CS1-UCS pairings and half were CS2-UCS pairings. As the average ITI was the same for all birds, the session length for this control group was twice as long as for the other groups. It was reasoned that this difference was preferable to giving this control group only half the number of CS2-UCS pairings as the experimental group.

If temporal contiguity with an unconditioned reinforcer is sufficient to establish a stimulus as a conditioned

reinforcer, then CS2 should acquire as much strength in this phase as CS1 did in the pretraining phase for the experimental birds. Therefore the CS2-UCS relationship in this phase was made as similar as was experimentally possible to that of the CS1-UCS relationship in the previous phase. Thus conditions were optimal for obtaining blocking in the experimental birds in this phase.

Test for blocking. The next experimental session began with a ten minute refresher of the previous phase. Next, the keylights were turned on, and the spontaneous recovery of key-pecking was measured for ten minutes or until the rate declined to four or fewer pecks per minute. The test for blocking began with two forced-choice trials. First the less preferred key, as determined by the last 12 sessions of baseline responding, was illuminated, and the first peck to this key was followed by a 3 sec presentation of CS1. Next, that key was darkened and the other key was illuminated. A peck to this key was followed by a 3 sec presentation of CS2. At this point there was a 10 sec blackout; then both keys were illuminated and stayed on for the remainder of the session and for all subsequent sessions. Pecks were followed by the relevant CS (never with food) on concurrent VI 15 schedules, with a 1 sec changeover delay, until rates of responding declined to baseline levels. (Pigeons were required to persist for at least 1 sec on a key [the changeover delay] in order for a response to be

reinforced. That is, the first peck to a key was never reinforced; only pecks following the first peck by a second or more met the schedule requirement for reinforcement. Otherwise reinforcement for a response to, say, the left key, might adventitiously strengthen preceding responses to the right key. Cf. Catania, 1963.) Left and right keypecks and the time of their occurrence were recorded to the nearest twentieth of a second since the start of the session. Note that for the experimental and L/T birds the less preferred key produced CS1; thus the test was biased against demonstrating a blocking effect.

Observation of the Birds

Each bird was observed through the one-way mirror in the door of the chamber for at least five minutes per session during the test session and at least half of the training sessions. A brief description of the behavior of the bird in each stimulus condition was recorded.

CHAPTER 3

RESULTS AND DISCUSSION

Overview

All 24 birds completed the study. Three of the older birds were slow to be shaped and adapted poorly to changes of conditions in the early stages of the experiment; they responded to stimulus changes and food delivery by freezing. By the third day of the pretraining phase, however, all birds appeared to be equally well adapted to the experimental conditions. No systematic differences between older birds and younger birds were evident in the test condition.

In the baseline phase, even after prolonged training, most birds preferred one key to the other. (The term 'preference,' here, is used only as a convenient term meaning a greater observed frequency of pecking one key than the other. Similarly, 'preference for CS1' means only that the key that 'produced' CS1 was pecked more frequently than the other key. Nothing is implied about the emotional state of the birds or about covert behavior, desires or 'acts of choice,' or even that CS1 was necessarily a variable controlling the pecking of that key.) Relative preferences

for the preferred key (pecks to preferred key divided by total pecks) were calculated for the last 12 days of the baseline condition for all birds. (See Table 3.) A relative preference of 0.5 indicates equal responding on both keys, while a relative preference of 0.67 indicates a two to one preference for one key. Relative preferences ranged from 0.50 to 0.65 with a median preference of 0.535. Only two birds showed a preference greater than 0.58 (a 1.38 to 1 ratio) and no bird preferred a key with more than a 1.85 to 1 ratio.

In the test phase, all of the experimental birds reversed their baseline preferences and pecked the key followed by CS1 more than the key followed by CS2. Four of the eight pecked the CS1 key more than the CS2 key by more than a two-to-one margin (relative preference > 0.67), and the relative preference of the remaining four birds for CS1 was greater than the median relative preference of all birds in the baseline condition for either key (0.535). The mean relative preference for CS1 was 0.67 with a range of 0.54 - 0.84. (See Table 3.)

In control group L/T, six of the eight birds reversed their baseline preferences, but of these only one preferred the CS1 key by as much as two to one and only three others preferred CS1 more than the median for all birds under the baseline condition. Two birds preferred the CS2 key, one by a wide margin. The mean relative preference for CS1 was

Table 3

Baseline and test data.

Bird #	Group-CS1	Baseline Pref for CS1 Key	Baseline Pref for Preferred Key	Test: CS1/CS2 Pecks	Test: Relative Pref for CS1
18	Exp Tone	0.47	0.53	803/259	0.76
16	Exp Tone	0.48	0.52	447/274	0.62
6	Exp Tone	0.45	0.55	1778/337	0.84
5	Exp Tone	0.35	0.65	655/555	0.54
9	Exp Light	0.50	0.50	1302/609	0.68
17	Exp Light	0.47	0.53	809/536	0.60
1	Exp Light	0.45	0.55	1115/394	0.74
3	Exp Light	0.42	0.58	1204/943	0.56
4	C(L/T) Tone	0.43	0.57	440/336	0.57
10	C(L/T) Tone	0.49	0.51	97/135	0.42
12	C(L/T) Tone	0.50	0.50	1107/882	0.56
11	C(L/T) Tone	0.49	0.51	677/654	0.51
2	C(L/T) Light	0.48	0.52	1098/544	0.67
13	C(L/T) Light	0.44	0.56	300/913	0.25
14	C(L/T) Light	0.47	0.53	500/445	0.53
15	C(L/T) Light	0.45	0.55	1550/1306	0.54
7	C(LT)	----	----	451/578	0.44
8	C(LT)	----	----	447/435	0.51
20	C(LT)	----	----	731/640	0.53
19	C(LT)	----	----	600/662	0.48
21	C(LT)	----	----	71/82	0.46
22	C(LT)	----	----	852/740	0.54
23	C(LT)	----	----	306/530	0.37
24	C(LT)	----	----	533/466	0.53

0.50 with a range of 0.25-0.67 (Table 3). Note that the mean, seemingly ideal for a control group, does not capture the distribution very well, but arises from the fact that one bird preferred CS2 so strongly.

In control group LT there was no pretraining and hence no criterion for determining the numerator of the relative preference statistic. To consistently put the pecks to the preferred key in the numerator would give a spuriously high standard against which to compare the other groups. (Even so, we get a mean relative preference for the preferred key of only 0.54 when we do so.) Consequently, the key that determined the numerator of the statistic for each bird was randomly assigned. The mean relative preference, obtained in this way, was 0.48 with a range of 0.46 - 0.63 (Table 3).

The experimental group, then, was evenly divided between birds that showed a striking preference for CS1, i.e. a preference beyond the range of the baseline data, and birds that showed a moderate preference, one that overlapped the top half of the baseline distribution. The center of the distribution of birds in control group L/T was comparable to the that of the baseline distribution, but the range and variability of the data were greater. Finally, the distribution of control group LT was comparable to that of the baseline distribution.

Representative cumulative records are presented in Figures 2-5. A cumulative record provides a graphic representation of the rate of responding. As cumulative responses are graphed on the ordinate and time on the abscissa, the rate of responding is determined by the slope of the line. Presentations of the reinforcer are represented by a short diagonal slash. If the bird responds in the presence of the reinforcer, as in parts of the records in Figures 2 and 5, the slash appears as an irregular "v" and the continuity of the curve is frequently broken, owing to the angle of the pen and the curvature of the drum on which the paper moves. After approximately 600 responses the pen returns to the axis and a new curve is generated. In Figures 2 through 5 successive curves have been nested to conserve space.

Bird 6 was the bird in the experimental group with the greatest preference for the pretrained stimulus. The left panel of Figure 2 represents this bird's pattern of responding on the first test day, and the right panel represents the responses on the second test day with reinforcers reversed. Preference for the pretrained stimulus is indicated by the dramatic difference in slope between the responses to the key producing the tone (upper left) and responses to the key producing the light (lower left). Even on the second day of testing, as extinction is setting in, the tone key is pecked considerably more than the light key.

Fig. 2. Cumulative records of Bird 6 (experimental bird, CS1 = Tone) on the first day (left panels) and second day (right panels) of testing. Responses in the test for spontaneous recovery are shown at (a) and (b). On the second day, the consequences of responding on the keys were switched.

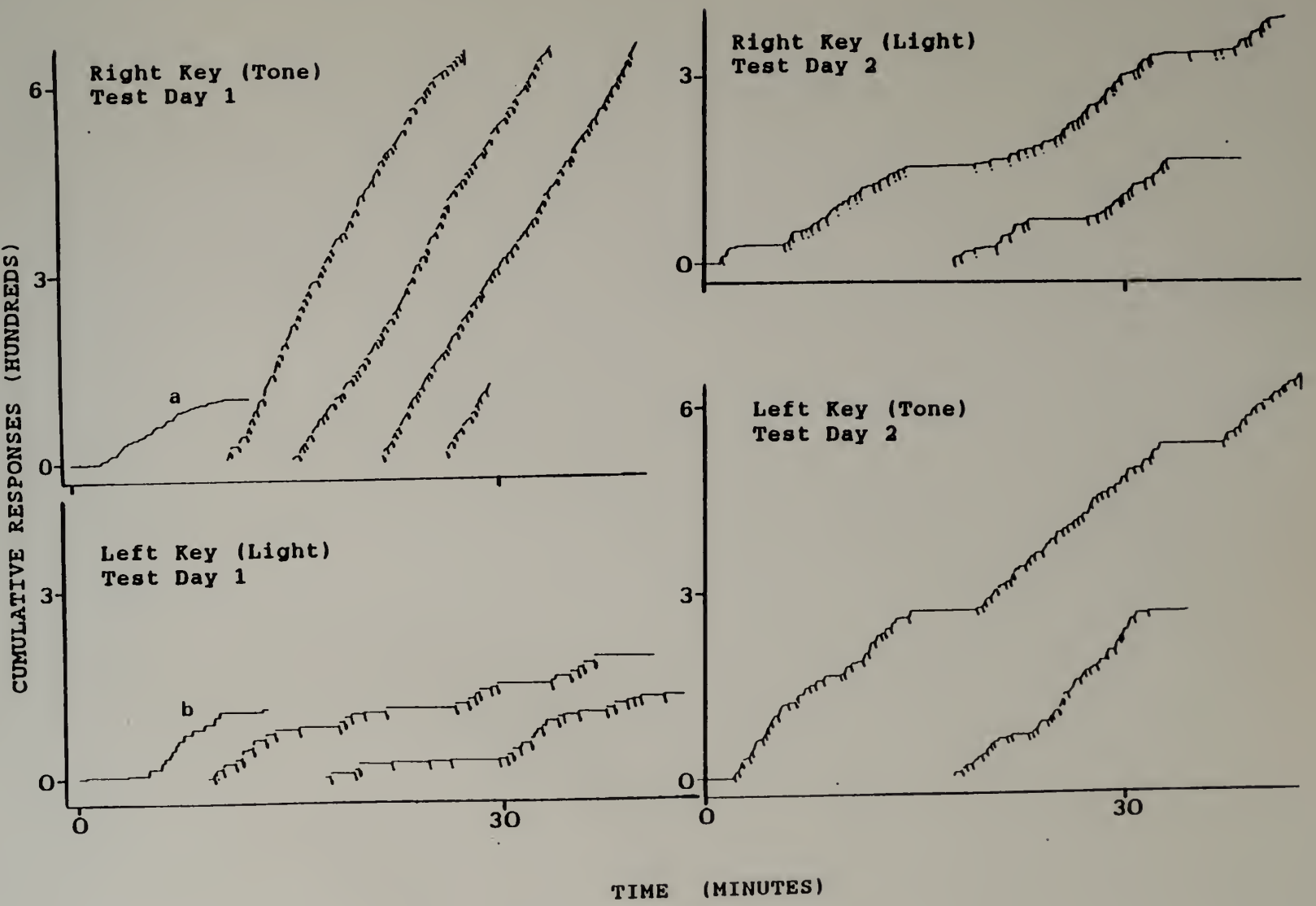

Right Key (Tone)
Test Day 1
Right Key (Light)
Test Day 2
Left Key (Light)
Test Day 1
Left Key (Tone)
Test Day 2
a
b
6
3
0
30
CUMULATIVE RESPONSES (HUNDREDS)
TIME (MINUTES)

Fig. 3. Cumulative records for Bird 15 (control bird (L/T), CS1 = Light). Responses in the test for spontaneous recovery are shown at (a) and (b). After the one hour test session the bird remained in the chamber with the keylights lit, but responding did not have any scheduled consequences. The ensuing extinction curves are shown at (c) and (d).

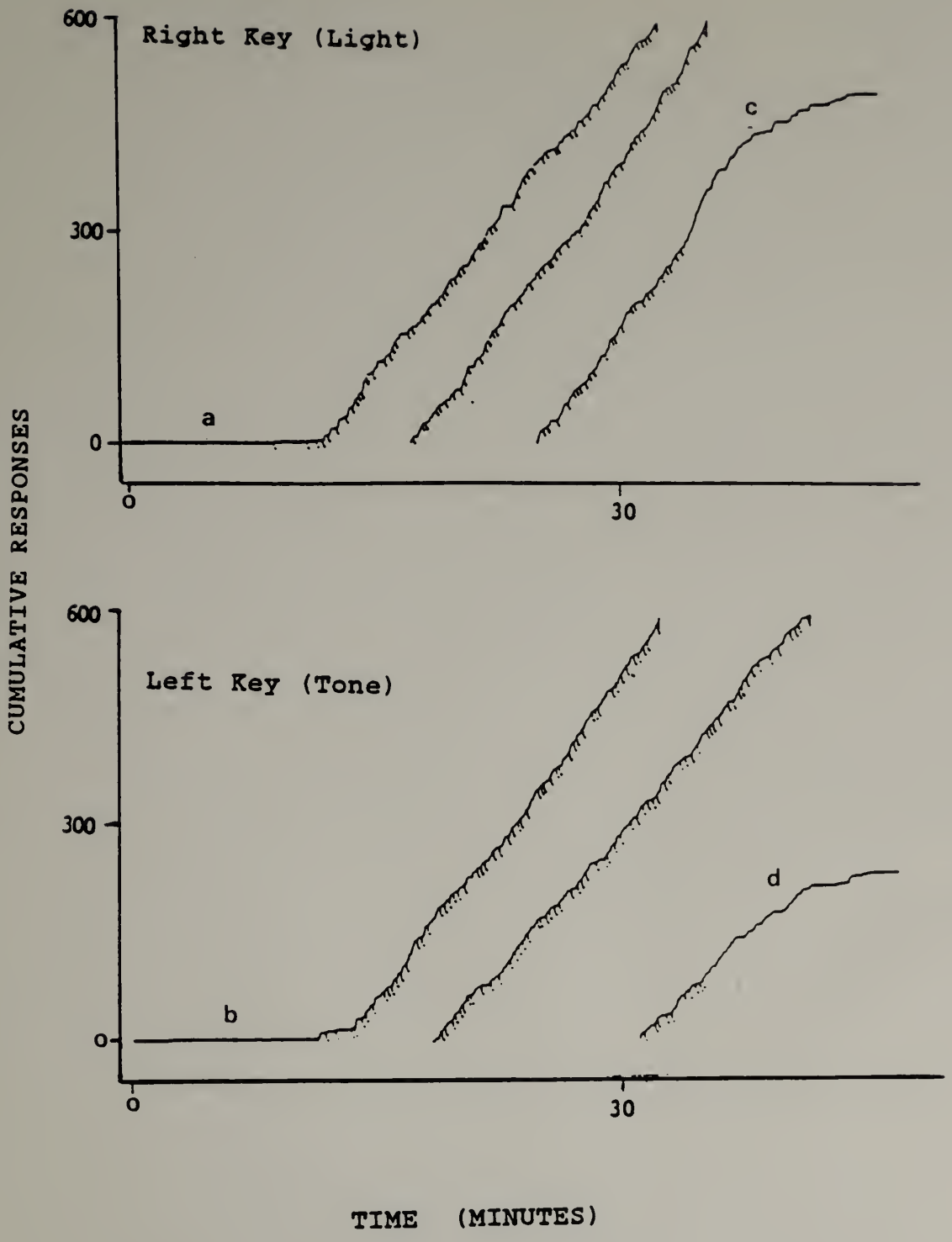

Right Key (Light)
600
300
0
a
c
0
30
Left Key (Tone)
600
300
0
b
d
0
30
CUMULATIVE RESPONSES
TIME (MINUTES)

Fig. 4. Cumulative record for Bird 20 (control bird (LT)). Note the decline in rate as the session progresses.

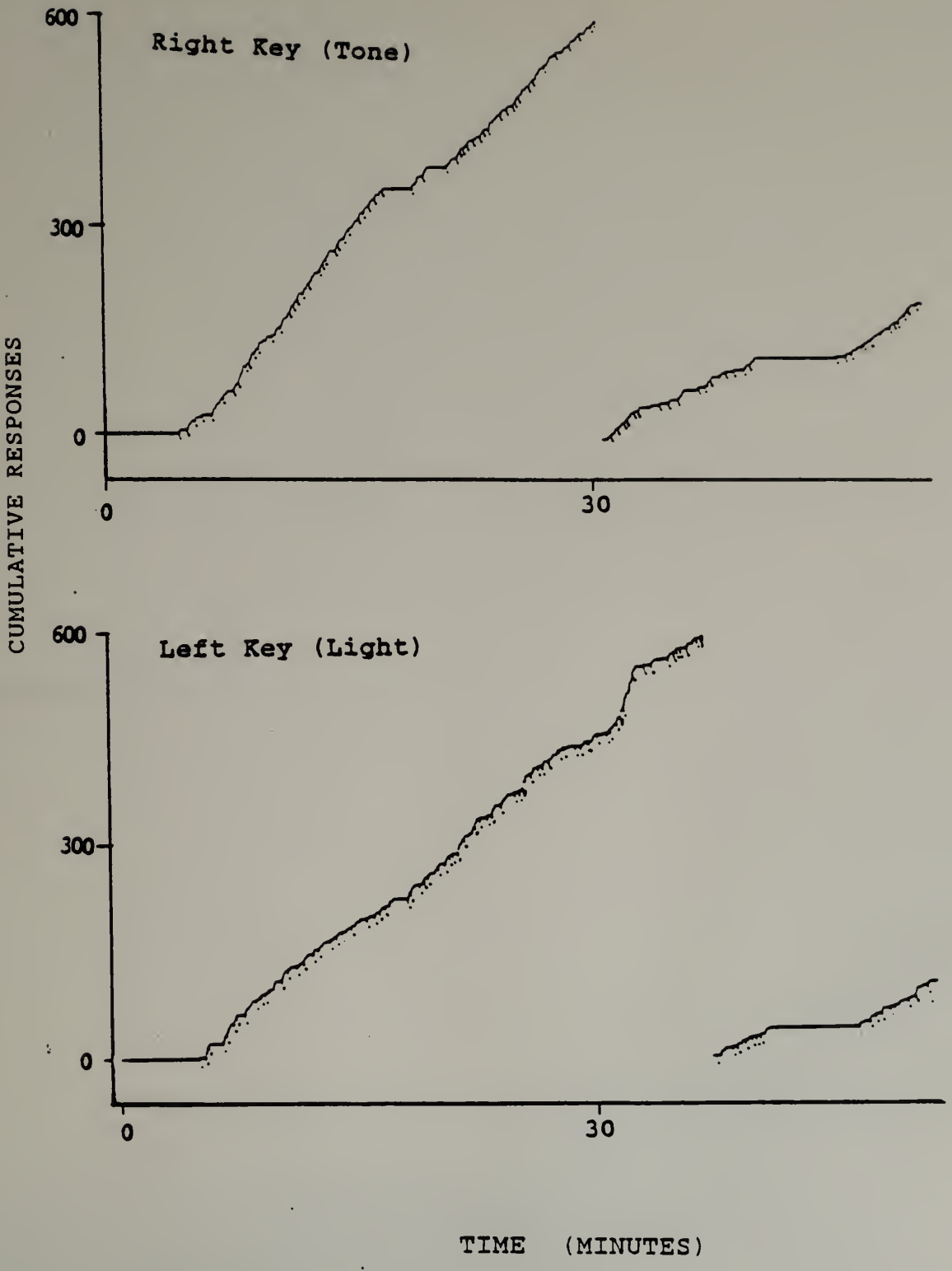
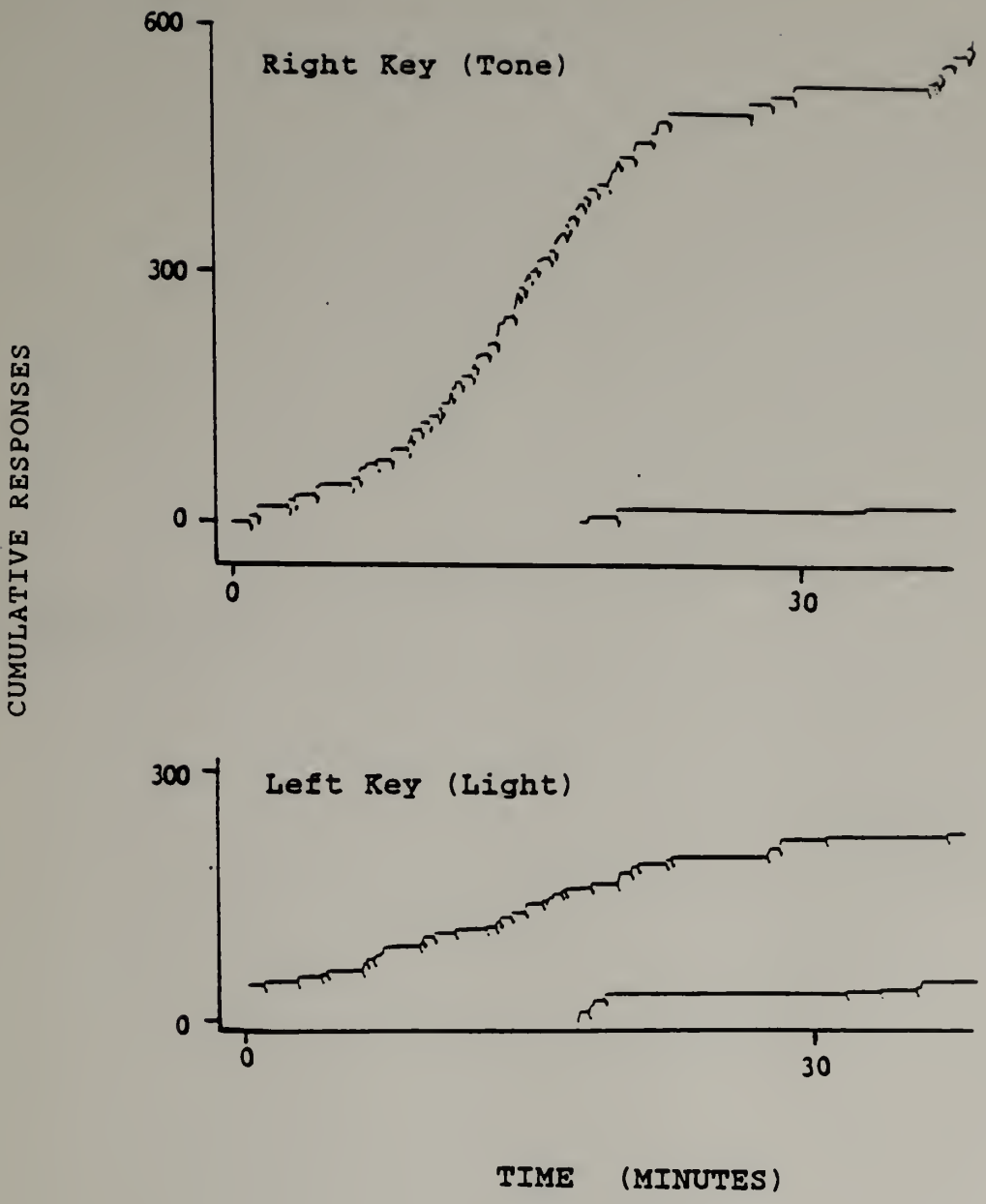

Right Key (Tone)
600
300
0
0
30
Left Key (Light)
600
300
0
0
30
CUMULATIVE RESPONSES
TIME (MINUTES)

Fig. 5. Cumulative record of Bird 5 (experimental bird, CS1 = tone) on the second day of testing. The rate of responding declines markedly in the second half of the session.


600
300
0
Right Key (Tone)
0
30
CUMULATIVE RESPONSES
300
0
Left Key (Light)
0
30
TIME (MINUTES)

Bird 15 was in control group L/T. It responded at comparable rates on the two keys with some preference for the pretrained stimulus (light). (See Figure 3.) At the end of the first one-hour test session the bird was left in the chamber with the keylights on, but no reinforcers were delivered. The ensuing extinction curve is shown in the far right of each panel.

Bird 20 represents control group LT. It responded at a moderate rate on both keys, and the pattern of behavior began to break down on both keys near the end of the one-hour session (Figure 4).

The second one-hour session of Bird 5, another experimental bird, is shown in Figure 5. This shows the eventual extinction of responding maintained by the tone and the light. Preference for the pretrained stimulus is clear until the pattern of responding begins to break down about halfway into the session.

Statistical Tests

Three statistical tests were run, an overall F test and two contrasts, one between the mean of the experimental group and the mean of each of the two control groups. As shown in Table 4 there is some heterogeneity of variance between groups, with the variance of control group L/T being over four times greater than that of control group LT. This

Table 4

Relative preference statistics.

	Experimental	Control L/T	Control LT
Mean	0.6681	0.5049	0.4812
Variance	0.0105	0.0147	0.0032

Variance of Means : 0.010355

Pooled Variance of Groups : 0.00944

Overall F Test

$$F_{(2,21)} = \frac{(N)(\text{Var Means})}{\text{Pooled Variance}} = \frac{(8)(0.010355)}{0.00944} = 8.77\ *$$

Contrast 1: Experimental vs. Control L/T

$$F_{(1,21)} = \frac{(M_E - M_{L/T})^2}{[(\text{Pooled Var})(2/8)]} = \frac{0.027}{0.00944/4} = 11.28\ *$$

Contrast 2: Experimental vs. Control LT

$$F_{(1,21)} = \frac{(M_E - M_{LT})^2}{[(\text{Pooled Var})(2/8)]} = \frac{0.035}{0.00944/4} = 14.80\ *$$

Contrast 3: Control L/T vs. Control LT

$$F_{(1,21)} = \frac{(M_{L/T} - M_{LT})^2}{[(\text{Pooled Var})(2/8)]} = \frac{0.00056}{0.00944/4} = 0.24$$

Criterion $F_{(2,21)}$ (alpha = .05) = 3.47

Criterion $F_{(1,21)}$ = 4.32

Scheffe Criterion F for 3 Contrasts = $(3-1)F_{(2,21)}$ = 6.94

violates one of the assumptions underlying the F test, leading to an inflation of the alpha level. However, simulations by Myers (reported in Myers, 1980) indicate that as long as the sample size is the same in all groups this inflation is slight. Even with n of five and a 20 : 1 ratio of variances, an alpha level of .05 was inflated to only .07. As the sample size is larger in the present study, and the ratio of variances much smaller, it appears that the heterogeneity of variance can be ignored.

The omnibus F test was run first to determine if there were significant differences among the means ($F_{(2,21)} = 8.27$; $p < .005$). As there was a clear difference, the experimental group was contrasted first with control group L/T ($F_{(1,21)} = 10.63$; $p < .005$) and then with control group LT ($F_{(1,21)} = 13.94$; $p < .005$). The error rate for this family of tests is well below .05. Even if, as a conservative estimate (since the three tests are not independent), .05/3 were used as the alpha level for each test, they would all be significant.

As noted above, the relative preferences of control group L/T were more variable than those of control group LT. To assess the extent of this difference an F statistic was computed, with the result: $F_{(7,7)} = 4.62$; $p < .05$. This confirms what is obvious from looking at the data, namely, that Phase 1 training was not neutral for control group L/T,

though different birds appear to have been affected in different ways.

The statistical tests support the hypothesis that the three groups of birds are different on the relative preference measure. How we interpret these differences will depend on a more detailed analysis of the data.

Reinforcement Function vs. Motivational Function

Before evidence for the blocking of conditioned reinforcement can be adduced, we must demonstrate that a conditioned reinforcement effect occurred at all. Necessary but not sufficient evidence for conditioned reinforcement is an increase in rate of the behavior on which the putative conditioned reinforcer is contingent. Table 5 shows the rate of keypecking in the last ten minutes of the test for spontaneous recovery and in the first ten minutes of the conditioned reinforcement contingency. All 24 birds increased their rate of keypecking when the contingency was instituted, and for most birds the increase in rate was dramatic. An inspection of representative cumulative records is perhaps more compelling. In the left panel of Figure 2, responses recorded by the short curves at (a) and (b) were emitted in the test for spontaneous recovery; the remaining responses were emitted in the test for blocking. The effect of the contingency is clearly shown by the change in slope when the contingency was begun. In Figure 3, the

Table 5

Responses in extinction and reinforcement phases. Responses in the last ten minutes of the test for spontaneous recovery and the first ten minutes of the test for conditioned reinforcement are listed. Most birds increased dramatically when the contingency was instituted. Note that rate of responding in spontaneous recovery was a poor index of the rate in the reinforcement phase.

Bird #	Spontaneous Recovery	Conditioned Reinforcement
18	42	187
16	6	216
6	210	510
5	74	107
9	124	277
17	46	211
1	0	221
3	17	466
4	0	165
10	37	52
2	199	205
11	95	322
12	67	843
13	22	416
14	11	154
15	1	402
7	209	278
8	2	56
20	19	448
19	97	240
21	13	33
22	86	302
23	33	166
24	182	316

test for spontaneous recovery is again shown at (a) and (b). Only one response was emitted in the ten-minute period shown. (It appears as a slight blip in the line in the lower panel.)

Since key pecking was never reinforced after the baseline phase of the study, the increase in responding cannot be attributed to the discriminative function of the conditioned stimuli. However it must be shown that the increase is not the result of the motivational function of the stimuli. A stimulus is said to have a motivating effect if it increases the strength of a variety of elicitation processes (Donahoe & Wessells, 1980). In the present context, it is possible that the periodic presentation of conditioned elicitors (CS1 and CS2) alters the strength of key pecking under the control of the keylights, much as the periodic presentation of food in a fixed interval (FI) schedule can alter the probability of polydipsia and other adjunctive behavior in rats. Other researchers who have studied conditioned reinforcement using yoked controls have found that there is indeed a motivating effect of the presentation of putative conditioned reinforcers, but that there is a larger effect which must be attributed to the conditioned reinforcement function itself.

In the present experiment, a general motivating effect would reveal itself by an increase in responding on both keys. If there were to be any differential effect, we would

expect it to favor the key that had been preferred during baseline. At least, there appears to be no reason why there should be a differential effect in favor of the less preferred key. Consideration of data from the experimental birds in Table 3 reveals that the rate of responding on the key preferred during baseline was considerably less than on the other key. Several birds responded almost exclusively on the other key. This suggests that the increase in responding is due to the specific consequence of responding and not to general arousal or to a motivational function of the procedure.

As further evidence that the increase in responding is specific to the contingent stimulus, we can consider the behavior of the birds for which the contingency was changed on the second day of testing. As shown in Figure 2, Bird 6 reversed its key preference when the contingency was reversed. That is, when the consequence of pecking the left key changed from tone presentation to light presentation, or vice versa, the bird switched its preferred key after a burst of responding on the light key. Most birds did not respond enough on the second day to be tested for this effect; however, the shift in preference of the remaining birds is hard to reconcile with the suggestion that the apparent reinforcing effect of the contingent stimuli was due to motivational variables.

It is possible to argue that a motivational variable would have differential effects on key pecking. If a light is a motivating stimulus, and if it is presented immediately following a peck to, say, the left key, then we might expect more pecks to the left key than the right key, since the bird is poised to peck the left key again. This would be a cogent argument if the birds remained at the key that 'produced' the stimulus. However, the birds typically did not remain at the response key when the putative conditioned reinforcer was presented, especially when the stimulus was the red light. Rather, the birds oriented toward the stimulus or toward the hopper. When the red light was presented birds characteristically responded by leaning backward and looking at the light, and would often jump, stretch, or peck toward the light as long as it was on. Neither key was in a relatively favorable position to be pecked when the stimulus was terminated. It appears, from this strong and stereotypical behavior of the birds, that the conditioned stimuli served both motivating and eliciting functions, but it seems equally clear that they served a reinforcing function as well.

Unconditioned vs. Conditioned Reinforcement

It has been shown that, under some conditions, the onset of a seemingly neutral stimulus such as a tone or light will function as a reinforcer without any pairing with

a known unconditioned reinforcer. In the present study, two lines of evidence indicate that the strengthening of keypecking by the tone and light was primarily a conditioned function rather than an unconditioned function. First, the strengthening effect in the experimental birds was stronger in CS1 than in CS2, regardless of whether CS1 was the tone or the light. If the reinforcing effect were wholly unconditioned, it presumably would not vary with Phase 1 training. Second, the reinforcing effect extinguished when the nominal unconditioned reinforcer was withheld (though it must be noted that for some birds extinction was prolonged). The responding of most birds extinguished in one experimental session, but others required two one-hour sessions. (See Figure 5 for a representative extinction curve in the test phase.)

Blocking vs. Overshadowing

In order to conclude that the experimental birds' preference for CS1 was due to the blocking of CS2 by CS1, it is necessary to rule out the possibility that the effect was due to overshadowing. Although the parametric study attempted to find appropriate stimulus parameters, we must examine the pattern of response preferences in the actual experiment to determine if the conditioned stimuli were, in fact, equally effective as blocking stimuli. If the four experimental birds that provided the most convincing evidence of blocking had all been pretrained with, say, the

light, we would question the validity of any conclusion about blocking.

If we label each bird as a tone bird or a light bird according to test preferences, we find that the two classes of animals are almost perfectly distributed among the groups of interest. Of the four experimental birds that showed clear evidence of blocking, two were light birds, two were tone birds. Consequently, the experimental birds that showed only weak blocking were half light birds and half tone birds. Of the eight birds in control group L/T only two preferred CS2 to CS1; for one, CS2 was the tone, for the other it was the light. Two birds in this group showed a strong preference for one stimulus; again they were evenly divided. Finally, of the eight birds in control group LT, five preferred the tone, three preferred the light. There is little evidence, then, that overshadowing contributed to the pattern of results. Considering how sensitive pigeons are to light intensity, as demonstrated by the parameter study, it is remarkable that the distribution of the preferences of the tone and light birds was as uniform as it is.

Differential Exposure to CS1 and CS2

The function of control group L/T was to determine the effect of differential exposure to CS1 and CS2. In the test phase all of the experimental birds preferred the key that

was followed by CS1. It is possible that this preference could be due to their having received twice as many pairings of CS1 with food as CS2. That there was a 'significant' difference between the experimental group and control group L/T suggests that the number of pairings was not sufficient to account for this preference. However, the performance of the control birds indicates that Phase 1 training was not neutral. On the average, birds in control group L/T did not prefer CS1 to CS2, but all save two birds preferred one stimulus to the other to at least a moderate extent (more than .535, the median baseline preference), and two birds showed more than a two-to-one preference for one stimulus. Not all birds deviated in the expected direction, however; two birds, including the one with the most extreme preference, favored CS2. Pretraining with CS1, then, appears to have contributed to variability in preference but not enough to account for the performance of the experimental group. Possible explanations for the pattern of results in control group L/T will be discussed below.

CHAPTER 4

GENERAL DISCUSSION

There were three noteworthy findings of this experiment, one of a procedural nature and two of a theoretical nature. First, the present procedure demonstrated a strong conditioned reinforcement effect, in contrast to the effects commonly observed in conditioned reinforcement studies. Second, stimulus parameters were found at which auditory and visual stimuli are roughly equipotent in pigeons, a result that constrains our interpretation of the experiments by LoLordo and his colleagues showing visual dominance in pigeons. Third, the preference of the experimental birds for pretrained stimuli exceeded that of the control birds, suggesting that the conditioned reinforcement function of stimuli can be blocked.

Conditioned Reinforcement Can Be Robust

Under the conditions of this procedure, most pigeons responded hundreds, or even thousands, of times over a period of an hour or more when the only consequence of responding was the intermittent presentation of a conditioned reinforcer. With many procedures, responding

maintained by conditioned reinforcement extinguishes quickly, and dispute has arisen whether conditioned reinforcement is even a genuine stimulus function. The procedural detail that most plausibly accounts for the present result is the prolonged pretraining with food as a reinforcer. Apparently, the reacquisition of a previously strong response provides a sensitive measure of the effectiveness of a conditioned reinforcer.

Other researchers have used similar procedures but typically not with so long a pretraining phase. Egger & Miller (1962) followed two days of shaping with four days of baseline training. Their extinction phase lasted only ten minutes. Hancock (1982) used a ten-day baseline with no extinction phase at all. In contrast, the shaping, maintenance, and extinction phases of the present experiment lasted about six weeks, with as many as seven one-hour extinction sessions required to reduce the key pecking to a low rate. Direct comparisons of response strength are not possible, since Egger & Miller and Hancock do not report their data in sufficient detail. However, Egger & Miller found that differences between animals in different conditions became negligible after twenty minutes of responding, and Hancock reports that all of his birds completed "at least one block of four test trials." Since his test trials were only 30 seconds long, it appears that levels of responding were unremarkable. If comparable test

procedures had been used in the present study, i.e. with ten minutes of extinction or none at all, the conditioned reinforcement effect would have been completely dwarfed by extinction responses. This suggests that baseline response strength was considerably greater in the present study, and that this response strength may be responsible for the high level of responding in the test condition.

Why does pretraining followed by extinction facilitate reacquisition of the response with a different reinforcer? Undoubtedly there are several factors. There may be generalization: During pretraining, responses were followed by conspicuous stimulus changes in several modalities. The hopper light came on, the houselight went off, and the hopper was raised with a distinctive noise, jarring the chamber. Approach to food was accompanied by visual, gustatory, and perhaps olfactory stimulation. The onset of a conditioned reinforcer, be it a tone or a light, is a conspicuous stimulus change, and both stimuli share properties with at least one dimension of food delivery. Relative to the consequences of responding in the extinction phase, the consequences of responding in the test phase are similar to those of the pretraining phase. Responding in the test phase, then, may be due in part to reinstatement of conditions similar to those of the pretraining phase. Note that while this may contribute to an increase in key pecking in the test phase, it does not account for the preference for CS1 observed in the experimental birds. Moreover, while

the test phase is more similar to the pretraining phase than the extinction phase, it is not similar in an absolute sense, at least as judged by humans. Generalization, then, may play a role in the birds' performance, but there are surely other important variables.

When a pigeon pecks a key on a VI schedule for a prolonged period, responses other than key pecks are not explicitly reinforced and presumably undergo extinction. Thus in a context in which key pecking occurs, other responses would be weak. The measurement of any subsequent strengthening of key pecking by a conditioned reinforcer would therefore be relatively "pure." That is, an increase in strength of responding would not be obscured by competition with other behavior. In contrast, when one uses a conditioned reinforcer to shape a novel response, one faces the usual problems of response shaping: Responding is variable at first, and responses of the terminal topography occur seldom, if at all. Crude approximations to the target response survive until extinguished, and other behavior may be strong as well. Using a target response that does not need to be shaped raises other problems, since any unconditioned strength of the response will contaminate performance. The prolonged pretraining and subsequent extinction may have served, then, to establish optimal conditions for measuring the reinforcing effect of the conditioned reinforcers. Other responses were weak, and the

strength of the target response had been continuously monitored.

A third possible contribution of the pretraining phase may have been to establish stimuli correlated with reinforcer-elicited behavior as discriminative stimuli for key pecking. That is, when the pigeon was nibbling, salivating, orienting toward the hopper or engaging in other behavior elicited by food, pecking the key was sometimes followed by more food. Interoceptive and proprioceptive feedback from approaching, ingesting, and digesting food may have become part of the context controlling key pecking. In the training phase of the present experiment, neutral stimuli were paired with food to establish them as conditioned reinforcers. Under these conditions the neutral stimuli presumably became conditioned elicitors as well, eliciting salivation, nibbling, and so on. Thus, the presentation of the putative conditioned reinforcers in the test phase of the experiment elicited responses which may have controlled key pecking. However, during the pretraining phase the strength of pecking was roughly equal on both keys. Discriminative control of key pecking by reinforcer-elicited stimuli, if it was a factor at all, would not seem to contribute to the preference of the birds for one key over another.

There are several explanations, then, for the unusual rates of responding in the test phase of this experiment.

It is possible, of course, that they all contribute in some measure to the response rate. It will be noted that two of the above accounts, namely, generalization and discriminative control by reinforcer-elicited responses, do not involve conditioned reinforcement at all. However, both of these accounts seem to be inadequate to account for the preferences of the experimental birds. Only an account that postulates a strengthening effect of the contingent stimulus seems to explain the results adequately.

"Visual Dominance" May Depend on Stimulus Parameters

Randich, Klein, & LoLordo (1978), using a procedure analogous to that in which selective attention is studied in humans (Colavita, 1974), found that, in pigeons, visual stimuli are dominant over auditory stimuli. Foree & LoLordo (1973) found that this was true when food was used as a reinforcer, but that the modality dominance was reversed for the avoidance of shock. The present results suggest that these conclusions must be qualified. When food is used as a reinforcer, the stimulus which will be dominant depends in part on the intensity of the stimuli. It is possible to find parameters at which each modality exerts roughly equal control and to find others at which the auditory modality is dominant. This qualification is supported by the parameter study, in which stimulus dominance was a function of light intensity when the auditory intensity was held constant, and was further confirmed by the 16 control birds for whom the

stimuli in both modalities became roughly equally effective conditioned reinforcers.

It is possible, of course, that the present results are peculiar to the procedure. Randich, et al., and Foree & LoLordo trained their birds with simple stimuli and tested preference with compound stimuli. In this study, birds were trained with compound stimuli and tested with simple stimuli. While this seems a minor difference, it underscores the need for a more thorough parametric analysis of stimulus dominance in the pigeon, the more so since the present study was not designed to assess the generality of the earlier work on stimulus dominance.

It will be noted that the results of the parameter study confirm the earlier findings in that nearly exclusive visual dominance was observed at the parameters used by Randich et al. and by Foree & LoLordo. The parameters at which stimuli were equally effective, i.e. a 2.5 cd/m^2 red light and an 85 dB tone, are not at all subjectively equivalent to a human observer. The tone is "loud and annoying" and the light "faint." One might argue that this merely confirms the dominance of the visual modality. However, "equivalence" must be measured relative to the organism of interest, and to assert the dominance of the visual modality as if it were an essential property of stimulus control in an organism is to go beyond the facts.

At other parameters we would assert the dominance of the auditory modality.

The Blocking of Conditioned Reinforcement

The primary finding of the present experiment, of course, is the difference in effectiveness of the putative conditioned reinforcers in the experimental and control birds. Does this justify the conclusion that the conditioned reinforcement function can be blocked? Certainly the weight of the evidence supports this contention, but the results are not unambiguous. On the average, the behavior of the experimental birds was different from the control birds, but the variability in their behavior suggests that we consider the birds individually. While our ultimate conclusions about blocking depend on a comparison of groups, blocking remains an individual phenomenon. The behavior of each bird is shaped by its own experiences without respect to the group it is in.

We may tentatively consider a preference for CS1 greater than two to one, or a relative preference of .67, to be a clear criterion for blocking, since this exceeds the baseline preference of any of the birds and also exceeds the preference of the control birds for CS1 during the test phase. By this criterion, the birds in the experimental group were evenly divided between those that demonstrated blocking and those that did not. Perhaps this criterion is

too strict. It may be that all of the birds blocked to some extent; as noted above, none of the experimental birds preferred CS1 less than the median baseline preference for all birds, and all of them reversed their baseline preferences. However, the evidence for blocking in four birds is not dramatic.

One interpretation of the behavior of these birds is that blocking occurred, but the test for blocking was too crude to detect it unambiguously. Blocking was assessed with a relative preference measure; the more a bird pecked the key that produced CS2, the less convincing the evidence for blocking. However, a pigeon can peck a key for reasons other than the conditioned reinforcing effect of the contingent stimulus. Any contribution from these other variables would serve, not to reduce blocking, but to reduce the size of our chosen measure of blocking. In fact, an extraneous variable that contributed to responding equally on both keys would also serve to lower the relative preference ratio. Even if there were total blocking of the conditioned reinforcement function of CS2, the relative preference measure could approach 0.50 if our test were superimposed on a high rate of responding on both keys. What are these other variables that might have contributed to responding on one or both keys? Several possibilities suggest themselves, some of which have been discussed above.

First, as noted earlier, the presentation of CS1 and CS2 may share stimulus properties with the presentation of food, perhaps no more than that both are sudden changes in stimulation. Stimulus generalization, then, might account for some key pecking on both keys, as we have no reason to assume that it would increase pecking to the CS2 key more than to the CS1 key. A related possibility, and one for which there is at least some evidence, is that there was stimulus generalization from the CS1 key to the CS2 key. All birds were shaped to peck both keys prior to the baseline phase. Shaping the pecking of one key was laborious for the experimenter and often required more than one session. Shaping the pecking of the second key was virtually effortless. Many birds pecked the second key 'spontaneously' in the course of shaping the first key. That there should be generalization is not remarkable, since the apparatus was designed so that the two keys should be as similar as possible except for position. Generalization between keys would have a much more serious effect on the relative preference measure than generalization from food to conditioned stimuli, since the effect would be to increase responding to the CS2 key while reducing responding to the CS1 key.

Second, the baseline phase was designed to establish a low rate of responding on both keys. Consequently, responses were never completely extinguished before the test phase. This baseline rate was usually quite low, but it

necessarily contributed to reducing the relative preference measure.

During the baseline phase a pattern of responding typically emerged. Birds would emit a burst of responses on one key, then switch to the other key and emit another burst of responses. This pattern was presumably shaped by the schedule contingencies, since it ensured that the birds would collect all the reinforcers in the shortest possible time. During the test phase many of the stimuli characteristic of the baseline phase, particularly response-produced stimuli, were reinstated. Most birds in the test phase continued to display the pattern characteristic of the baseline phase. Both aspects of this pattern, switching and bursting, would serve to raise the response rate on both keys independently of any conditioned reinforcement effect, thus damping the relative preference measure.

Finally, it is possible that the tone and light served an unconditioned reinforcing function to some extent. It has been shown that, under some conditions, stimulus change itself can function as a reinforcer (e.g. Kish, 1966). In the present experiment, any unconditioned effect of the stimuli, however slight, could contribute to the rate of responding on the CS2 key, thus lowering the relative rate of responding for CS1. All birds were observed during the first session of each new condition to assess the effect of the change and to be sure that the birds were exposed to the

contingency, i.e. that they ate promptly when food was delivered. These observations confirm that the stimuli were not neutral. On the first day of Phase 1 training, both the tone and light elicited some behavior, either an orienting response, a startle reflex, freezing, or 'sulking.' Most birds quickly adjusted to the presentation of the stimuli; that is, they were active, they ate readily, at least by the second presentation of food, and they showed little or no evidence of a startle response. Several birds adjusted slowly and ate readily only after half of the first session had elapsed. While these observations attest to the unconditioned eliciting function of the stimuli, it is not clear that they would serve to strengthen key pecking in an operant paradigm. There was no obvious reinforcing effect on behavior in the first session, but such an effect was hard to assess since the birds were typically not engaging in easily measurable responses when the stimuli were presented, and the occasional presentation of food was a confounding variable. However, that key pecking in the test session eventually extinguished and for most birds did not recover, suggests that the reinforcing function of the stimuli was conditioned, not unconditioned.

There are several variables, then, that may have contributed to responding on the CS2 key or may have reduced, relatively, the rate of responding on the CS1 key. These variables do not bear on the experimental question;

they merely reduce the precision of the chosen measure of the question. In this light, we can reconsider the performance of the eight experimental birds. It strongly suggests that the conditioned reinforcement function can indeed be blocked. For several of the birds the preference for CS1 far exceeded that of the control birds. Moreover, the blocking may have been total: the little responding on the CS2 key may have been due to the variables just discussed and not to the conditioned reinforcing function of CS2. The performance of the remaining experimental birds is consistent with blocking but not compelling. It is possible that all responding to the CS2 key was due to variables orthogonal to blocking, and that CS2 did not serve as a conditioned reinforcer at all. However, it is equally possible that a given procedure will produce different effects on different birds, ranging from total blocking to, perhaps, no blocking at all, and that the experimental birds reflect this range accurately.

Sources of Variability in the Experimental Birds' Behavior

Why should the procedure produce different results in different birds? Variability is doubtless inevitable in any experiment with living organisms, but one naturally hopes to reduce all variability that is under experimental control. With the advantage of hindsight it is possible to identify potential sources of variability, but it is not clear that all of them can be controlled.

Birds might differ in their sensitivity to auditory and visual stimuli, in which case the two potential conditioned reinforcers might not be equivalent. These differences might be genetic in origin, or they might arise from differential changes of acuity with age. The birds were all from a common breeding stock and as genetically similar as is practical, but they spanned several generations in age. So far as I know there is no reason to suppose that sensitivity to auditory or visual stimuli changes with age in pigeons or that they change differentially, but any doubt about this could be reduced by using birds of the same age, preferably young and inexperienced birds. The young birds in this experiment adapted more quickly to environmental changes than the older birds. Several of the older birds were easily "spooked" by novel events and seemed especially startled by the tone. I could see no difference in the overall pattern of results between young and old birds, but there were too few subjects per condition and too much variability per condition to draw strong conclusions on this score.

The intensity of the tone varied from one part of the chamber to another, with the greatest intensity being directly in front of the hopper. The range of this variability was on the order of 5 dB. Birds typically stood close to the keys with their heads high, but there was a

wide range of postures adopted by the birds at different times. It may be that the early trials of the blocking phase influence the subsequent course of blocking. If so, the location of the bird on its first trial might be of importance, especially in light of the sensitivity of the birds to differences in stimulus intensity. Mackintosh (1975a) and Mackintosh, Dickinson, & Cotton (1980) have shown that the magnitude of the blocking effect is not uniform throughout Phase II, that less blocking, if any, may occur on the first trial of Phase II. Variability in the behavior and orientation of the birds might compound this effect. The latter problem might be avoided by more sophisticated apparatus capable of delivering a more uniform auditory signal.

The effectiveness of an experimental manipulation in a study of this sort no doubt depends on a complex interaction of the organism with the experimental conditions. As just noted, the intensity of a stimulus may be regarded by the experimenter as a fixed parameter, but it will vary with the behavior and orientation of the organism. The effective intensity of an overhead red light will depend on whether the pigeon is looking straight up at the light, is oriented toward the keys, or is scanning the floor of the chamber, a species-typical foraging behavior. This problem is not entirely academic. After a pigeon has adapted to an experimental apparatus it spends much of its time exploring the floor of the chamber; once key pecking is established it

spends most of its time monitoring the intelligence panel; in the present experiment, birds given light-food pairings would monitor the top of the chamber, often by leaning back awkwardly and stretching upward. The intensity of the tone and the light were carefully equated by the experimenter, but whether they were effectively equivalent depended in part on the behavior of the birds.

Other differences in the behavior of the birds may have contributed to variability in the test results. The baseline phase was designed to equate the two response keys as discriminative stimuli controlling pecking. It succeeded to the extent that baseline preferences for one key never exceeded .65. However, a .65 relative preference is hardly an indication of indifference, and most birds behaved differently with respect to the two keys in ways that were not fully reflected in the relative preference measure. During baseline, most birds preferred the key on which pecking was first shaped. Moreover, many birds pecked one key more rapidly than they did the other for periods sometimes lasting several sessions. For one bird the topography of pecking differed on the two keys; it pecked the left key with discrete forceful pecks, but it operated the right key by nibbling at the crack between the key and the panel, its lower mandible closing the switch at a rapid rate. Another bird often turned from the right key to the one-way mirror and would bow, peck and growl at its

reflection, returning after a while to the right key, never to the left. This variability in behavior in the baseline phase suggests that predictions about preference based only on considerations of schedules of reinforcement are of limited accuracy when applied to individual organisms.

It is clear that in the present study the blocking phenomenon was measured against a variable baseline, and more important, that in some cases the conditions necessary for blocking may not have been met. These considerations suggests that the test of blocking was a conservative one and that the results favor the conclusion that the conditioned reinforcement function can be blocked.

Theoretical Considerations

The present findings are consistent with the unified reinforcement principle proposed by Donahoe that holds that changes in stimulus control in both the operant and classical procedures require a discrepancy between responses elicited by the unconditioned stimulus and responses elicited by the constellation of other stimuli present in close temporal proximity to the unconditioned stimulus (Donahoe, et al.; 1982). According to this formulation of the reinforcement principle, a procedure that blocks the eliciting function of a stimulus should block its reinforcing function as well. The blocking of the eliciting function was not assessed in this study, but the procedure

is analogous to many others in which blocking is found, and blocking would be predicted by modern "discrepancy" theories of reinforcement, of which the Rescorla-Wagner model (Rescorla & Wagner, 1972) is perhaps the best-known example. Therefore, the evidence for blocking of the conditioned reinforcement function suggests that the two stimulus functions vary together, a necessary finding under the unified reinforcement principle. In those formulations of the reinforcement principle that postulate that conditioning procedures change the "associative strength" of stimuli, formulations such as the Rescorla-Wagner model, I believe that the present results are a consistent finding but not a necessary one, for they do not equate the potential to elicit behavior with the potential to reinforce instrumental responses.

The present experiment was not designed to distinguish between reinforcement theories, and as far as I can see, the results are consistent with most, if not all, modern theories. However, it should be emphasized that the unified reinforcement principle makes a specific prediction about the outcome of the experiment. Indeed, the prediction is central to the principle. Theories that honor a distinction between unobservable learning and its behavioral manifestation, performance, do not stand to be confirmed or refuted by these results. The outcome is therefore not devoid of theoretical interest. A theory that makes specific, refutable predictions about directly observable

phenomena is apt to become more influential as its predictions are confirmed. In this light, the experiment is not entirely neutral.

REFERENCES

Ayres, J. J. B., Albert, M., & Bombace, J. C. (1987). Extending conditioned stimuli before versus after unconditioned stimuli: Implications for real-time models of conditioning. Journal of Experimental Psychology: Animal Behavior Processes, 13, 168-181.

Bersh, P. J. (1951). The influence of two variables upon the establishment of a secondary reinforcer for operant responses. Journal of Experimental Psychology, 41, 62-73.

Blanchard, R. & Honig, W. K. (1976). Surprise value of food determines its effectiveness as reinforcer. Journal of Experimental Psychology: Animal Behavior Processes, 2, 67-74.

Bombace, J. (1982). Interactions between Pavlovian first- and second-order conditioning. Unpublished doctoral dissertation, University of Massachusetts.

Brown, P. L., & Jenkins, H. M. (1968). Autoshaping of the pigeon's key-peck. Journal of the Experimental Analysis of Behavior, 11, 1-8.

Catania, A. C. (1963). Concurrent performances: Reinforcement interaction and response independence. Journal of the Experimental Analysis of Behavior, 6, 253-263.

Colavita, F. B. (1974). Human sensory dominance. Perception and Psychophysics, 16, 409-412.

Dickinson, A., Hall, G., & Mackintosh, N. J. (1976). Surprise and the attenuation of blocking. Journal of Experimental Psychology: Animal Behavior Processes, 2, 213-222.

Dinsmoor, J. A. (1950). A quantitative comparison of the discriminative and reinforcing functions of a stimulus. Journal of Experimental Psychology, 40, 458-472.

Donahoe, J. W., Crowley, M. A., Millard, W. J., & Stickney, K. A. (1982). A unified principle of reinforcement: Some implications for matching. In M. L. Commons, R. J. Herrnstein, & H. Rachlin (Eds.), Quantitative analyses of behavior: Vol 2. Matching and maximizing accounts (pp. 493-521). Cambridge, MA: Ballinger.

Donahoe, J. W. & Wessells, M. (1980). Learning, language and memory. New York: Harper & Row.

Egger, M. D. & Miller, N. E. (1962). Secondary reinforcement in rats as a function of information value and reliability of the stimulus. Journal of Experimental Psychology, 64, 97-104.

Foree, D. D. & LoLordo, V. M. (1973). Attention in the pigeon: The differential effect of food getting vs. shock avoidance procedures. Journal of Comparative and Physiological Psychology, 85, 551-558.

Frey, P. W. & Sears, R. J. (1978). Model of conditioning incorporating the Rescorla-Wagner associative axiom, a dynamic attention process, and a catastrophe rule. Psychological Review, 85, 321-340.

Hall, J. F. (1951). Studies in secondary reinforcement: I. Secondary reinforcement as a function of the frequency of primary reinforcement. Journal of Comparative and Physiological Psychology, 44, 246-251.

Hancock, R. A. (1982). Tests of the conditioned reinforcement value of sequential stimuli in pigeons. Animal Learning and Behavior, 10, 46-54.

Herrnstein, R. J. (1961). Relative and absolute strength of response as a function of frequency of reinforcement. Journal of the Experimental Analysis of Behavior, 4, 267-272.

Holland, P. C. (1984). Unblocking in Pavlovian appetitive conditioning. Journal of Experimental Psychology: Animal Behavior Processes, 10, 476-497.

Hyde, T. S. (1975). The effect of Pavlovian stimuli on the acquisition of a new response. Learning and Motivation, 6, 223-239.

Jenkins W. O. (1950). A temporal gradient of derived reinforcement. American Journal of Psychology, 63, 237-243.

Kamin L. J. (1968). Attention-like processes in classical conditioning. In M. R. Jones (Ed.), Miami symposium on the prediction of behavior: Aversive stimulation (pp. 9-31). Miami: University of Miami Press.

Kamin L. J. (1969). Predictability, surprise, attention, and conditioning. In B. A. Campbell and R. M. Church (Eds.), Punishment and aversive behavior (pp. 279-296). New York: Appleton-Century-Crofts.

Kelleher, R. T. (1956). Intermittent conditioned reinforcement in chimpanzees. Science, 124, 679-680.

Kelleher, R. T. (1958). Fixed-ratio schedules of conditioned reinforcement with chimpanzees. Journal of the Experimental Analysis of Behavior, 3, 281-289.

Kelleher, R. T. & Gollub, L. R. (1962). A review of positive conditioned reinforcement. Journal of the Experimental Analysis of Behavior, 5, 543-597.

Keller, F. S. & Schoenfeld, W. N. (1950). Principles of psychology. New York: Appleton-Century-Crofts.

Kish, G. B. (1966). Studies of sensory reinforcement. In W. K. Honig, (Ed.), Operant behavior: Areas of research and application (pp.109-159). New York: Appleton-Century-Crofts.

Leyland, C. M. & Mackintosh, N. J. (1978). Blocking of first- and second-order autoshaping in pigeons. Animal Learning and Behavior, 6, 391-394.

Mackintosh, N. J. (1975). Blocking of conditioned suppression: Role of the first compound trial. Journal of Experimental Psychology: Animal Behavior Processes, 1, 335-345. (a)

Mackintosh, N. J. (1975). A theory of attention: Variations in the associability of stimuli with reinforcement. Psychological Review, 82, 276-298. (b)

Mackintosh, N. J., Dickinson, A., & Cotton, M. (1980). Surprise and blocking: Effects of the number of compound stimuli. Animal Learning and Behavior, 8, 387-391.

Marchant, H. G., III, & Moore, J. W. (1973). Blocking of the rabbit's conditioned nictitating membrane response in Kamin two-stage paradigm. Journal of Experimental Psychology, 101, 155-158.

McCausland, D. F., Menzer, G. W., Dempsey, T. K., & Birkimer, J. C. (1967) Response contingent and noncontingent informative and redundant secondary reinforcers. Psychonomic Science, 8, 293-294.

Miles, R. C. (1956). The relative effectiveness of secondary reinforcers throughout deprivation and habit-strength parameters. Journal of Comparative and Physiological Psychology, 49, 126-130.

Miles R. C. (1970). Blocking the acquisition of control by an auditory stimulus with pretraining on brightness. Psychonomic Science, 19, 133-134.

Moore, J. W. & Stickney, K. A. (1980). Formation of attentional-associative networks in real time: Role of the hippocampus and implications for conditioning. Physiological Psychology, 8, 207-217.

Morse, W. H. & Skinner, B. F. (1958). Some factors involved in the stimulus control of operant behavior. Journal of the Experimental Analysis of Behavior, 1, 103-107.

Myers, J. L. (1979). Fundamentals of experimental design. Boston: Allyn & Bacon.

Neely, J. H., & Wagner, A. R. (1974). Attenuation of blocking with shifts in reward: The involvement of schedule-generated contextual cues. Journal of Experimental Psychology, 102, 751-763.

Nevin, J. A. (1973). Conditioned reinforcement. In J. A. Nevin and G. S. Reynolds (Eds.), The study of behavior: Learning, motivation, emotion, and instinct (pp. 155-198). Glenview, IL: Scott, Foresman and Company.

Palmer, D. C., Donahoe, J. W., & Crowley, M. A. (1985). Discriminated interresponse times: Role of autoshaped responses. Journal of the Experimental Analysis of Behavior, 44, 301-313.

Pearce, J. M. & Hall, G. (1980). A model for Pavlovian learning: Variations in the effectiveness of conditioned but not of unconditioned stimuli. Psychological Review, 87, 532-552.

Perkins, C. C., Jr., Beavers, W. O., Hancock, R. A., Jr., Hemmendinger, P. C., Hemmendinger, D., & Ricci, J. A. (1975). Some variables affecting rate of key pecking during response-independent procedures (autoshaping). Journal of the Experimental Analysis of Behavior, 24, 59-72.

Randich, A., Klein, R. M., & LoLordo, V. M. (1978). Visual dominance in the pigeon. Journal of the Experimental Analysis of Behavior, 30, 129-137.

Rescorla, R. A. (1977). Pavlovian second-order conditioning: Some implications for instrumental behavior. In H. Davis and H. M. B. Hurwitz (Eds.), Operant-Pavlovian interactions (pp.133-164). Hillsdale, NJ: Lawrence Erlbaum.

Rescorla, R. A. & Wagner, A. R. (1972). A theory of Pavlovian conditioning: Variations in the effectiveness of reinforcement. In A. H. Black and W. F. Prokasy (Eds.), Classical conditioning II: Current research and theory (pp. 64-99). Englewood Cliffs, NJ: Prentice-Hall.

Seligman, M. E. P. (1966). CS redundancy and secondary punishment. Journal of Experimental Psychology, 72, 546-550.

Skinner, B. F. (195). Are theories of learning necessary? Psychological Review, 57, 193-216.

Stickney, K. A. & Donahoe, J. W. (In preparation). Blocking: Effect of changing the instrumental response.

Thomas, D. R., Berman, D. L., Serednesky, G. E., & Lyons, J. (1968). Information value and stimulus configuring as factors in conditioned reinforcement. Journal of Experimental Psychology, 76, 181-189.

Thomas, D. R. & Caronite, S. C. (1964). Stimulus generalization of a positive conditioned reinforcer: II. Effects of discrimination training. Journal of Experimental Psychology, 68, 402-406.

Tomie, A. (1976). Retardation of autoshaping: Control by contextual stimuli. Science, 192, 1244-1246. (a)

Tomie, A. (1976). Interference with autoshaping by prior context conditioning. Journal of Experimental Psychology: Animal Behavior Processes, 2, 323-335. (b)

vom Saal, W. & Jenkins, H. M. (1970). Blocking the development of stimulus control. Learning and Motivation, 1, 52-74.

Wagner, A. R. (1978). Expectancies and the priming of STM. In S. H. Hulse, H. Fowler, & W. K. Honig (Eds.), Cognitive processes in animal behavior. Hillsdale, NJ: Erlbaum.

Williams, B. A. (1975). The blocking of reinforcement control. Journal of the Experimental Analysis of Behavior, 24, 215-225.

Wyckoff, L. B., Sidowski, J., & Chambliss, D. J. (1958). An experimental study of the relationship between secondary reinforcing and cue effects of a stimulus. Journal of Comparative and Physiological Psychology, 51, 103-109.

Zimmer-Hart, C. L. (1974). An investigation of first-order principles in second-order conditioning. Unpublished doctoral dissertation, Yale University.